- Orbit response matrix G_{ij}: $$G_{ij} = \frac{\partial x_i}{\partial \theta_j}(K_l, \vartheta_l, g_i, g_j, \ldots)$$
  where θ_j are corrector setting changes, x_i are measured orbits from these corrector settings, and $g_{i,j}$ are BPM/corrector gains.

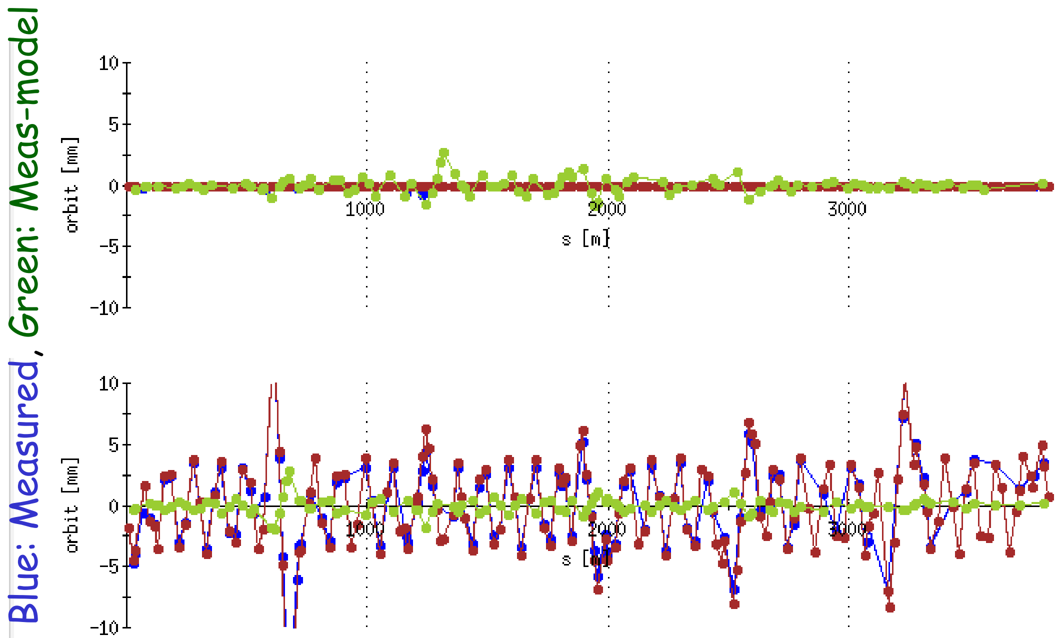
- Compare model and measured response matrices G_{ij}, and iteratively make model changes to minimize χ^2 difference between model and measurement:
  - *Model changes* ***b*** *include quad gradients, BPM/corr gains, …*
  - *Measures gradient errors, BPM/corr gain errors, skew errors, …*

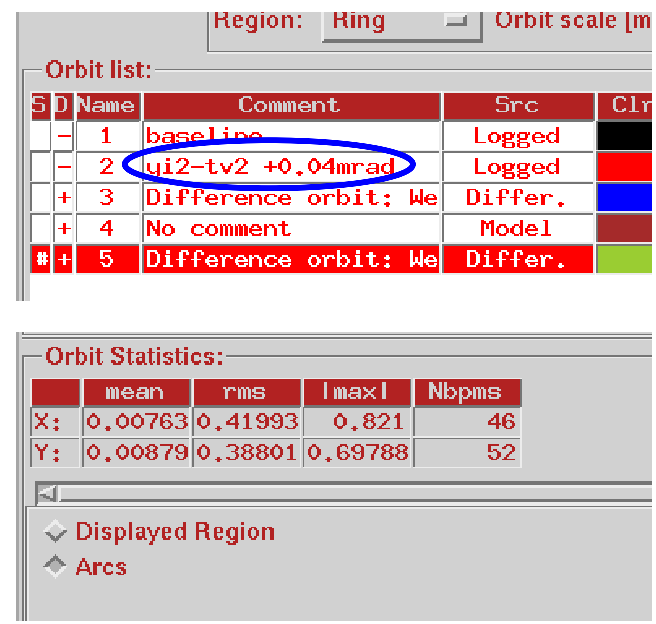
$$\chi^2(\mathbf{b}) = \sum_{ij}\left(\frac{G_{ij}(\mathbf{b})^{\{x,z\},\mathrm{model}} - G_{ij}^{\{x,z\},\mathrm{meas}}}{\sigma_{M_{ij}}}\right)^2 + \sum_{x,z}\left(\frac{\nu_{x,z}(\mathbf{b})^{\mathrm{model}} - \nu_{x,z}^{\mathrm{meas}}}{\sigma_{\nu_{x,z}}}\right)^2$$

  - *This is an overconstrained nonlinear minimization problem; dim(**b**) < dim(i) x dim(j)*

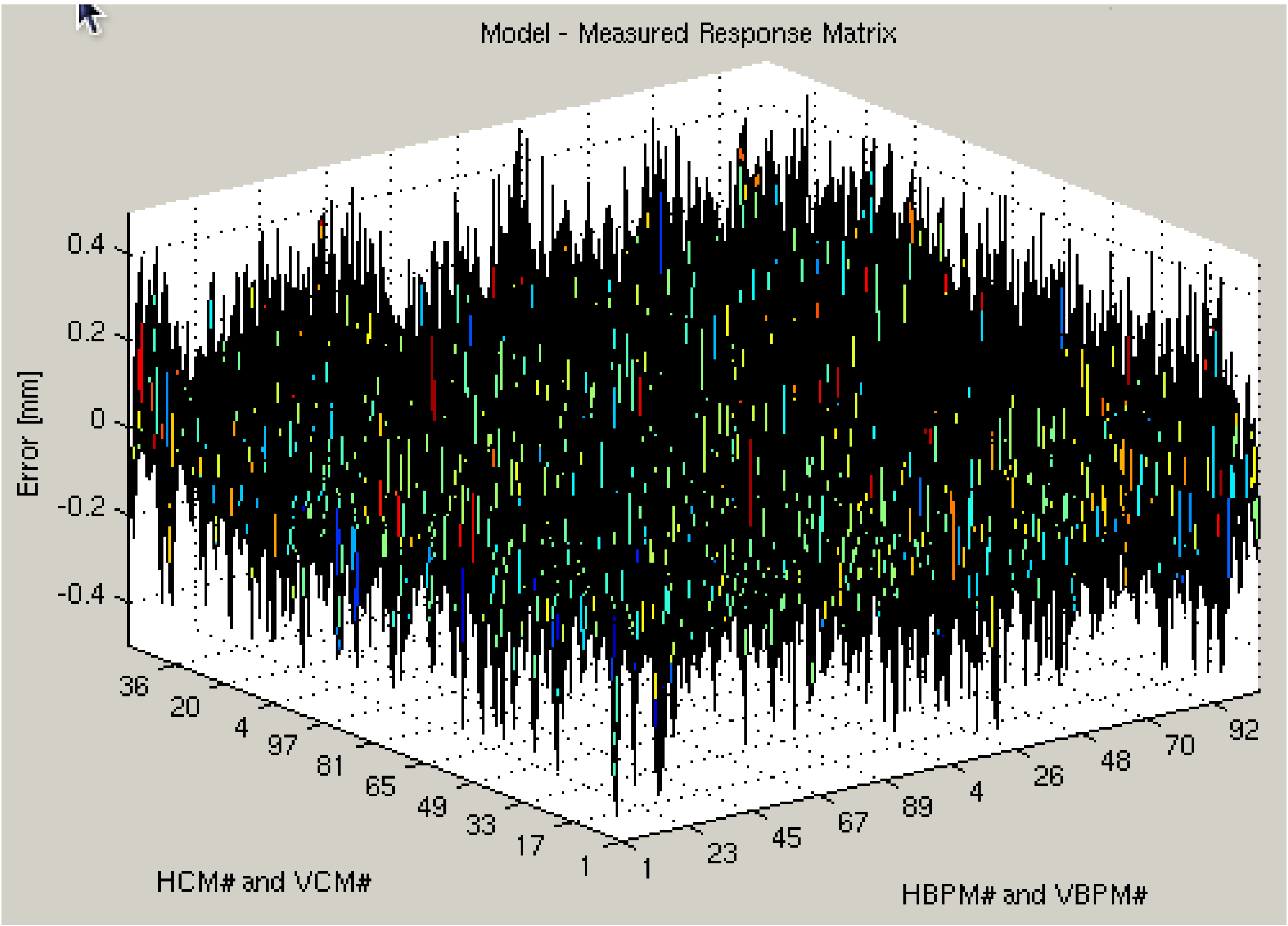
ORM APEX Dec 5 2007

- Some problems with beam early in shift
  - y2-q89, BTA Geneva foil; 2.5 hours time with both beams
- Acquired ORM responses in both rings: dAu80::store
  - 109 horizontal (nearly all), 59 vertical correctors
  - 216 BPMs used in total; snake and DX BPMs excluded in analysis
  - Difference orbits double-checked "live" through APEX

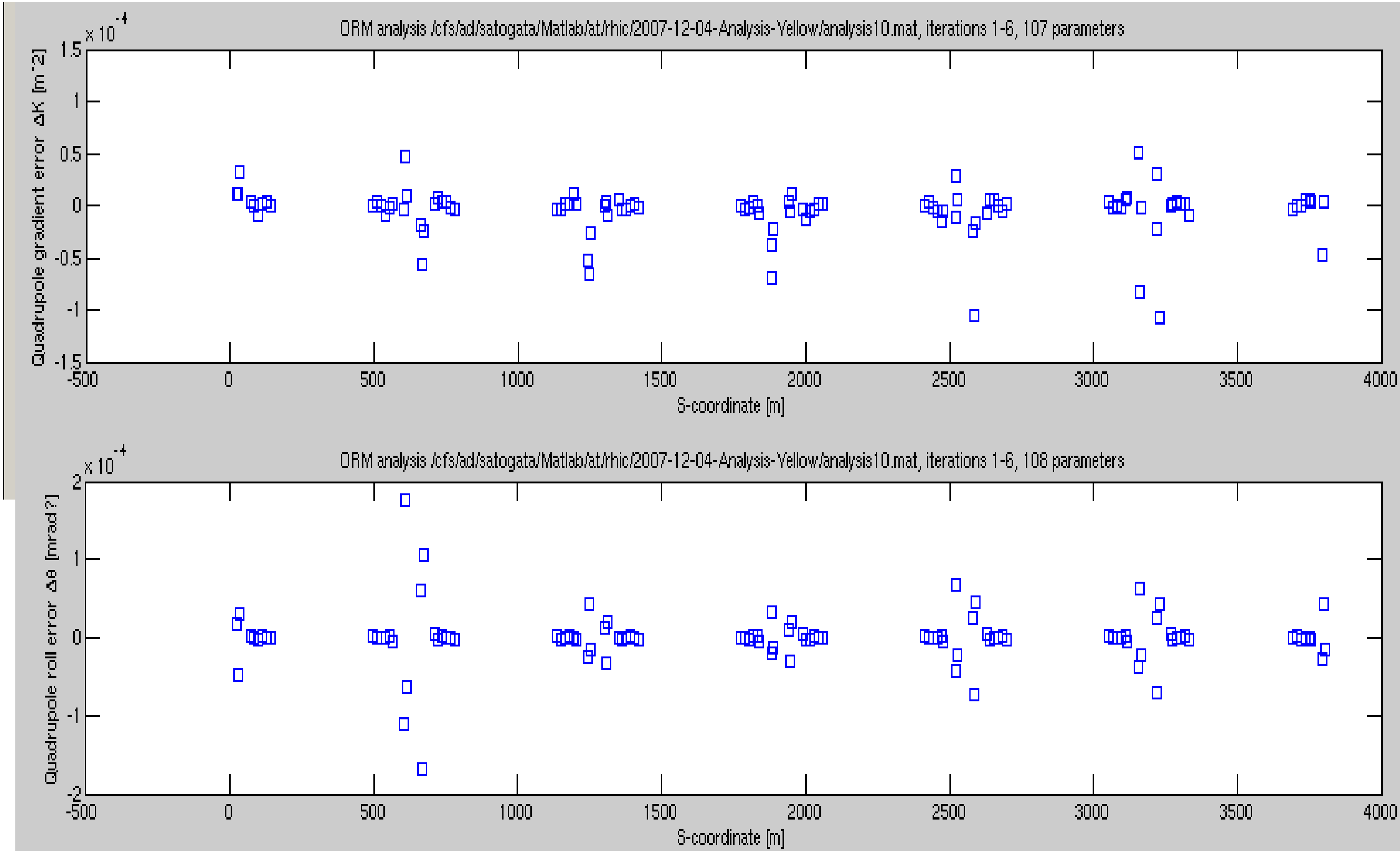




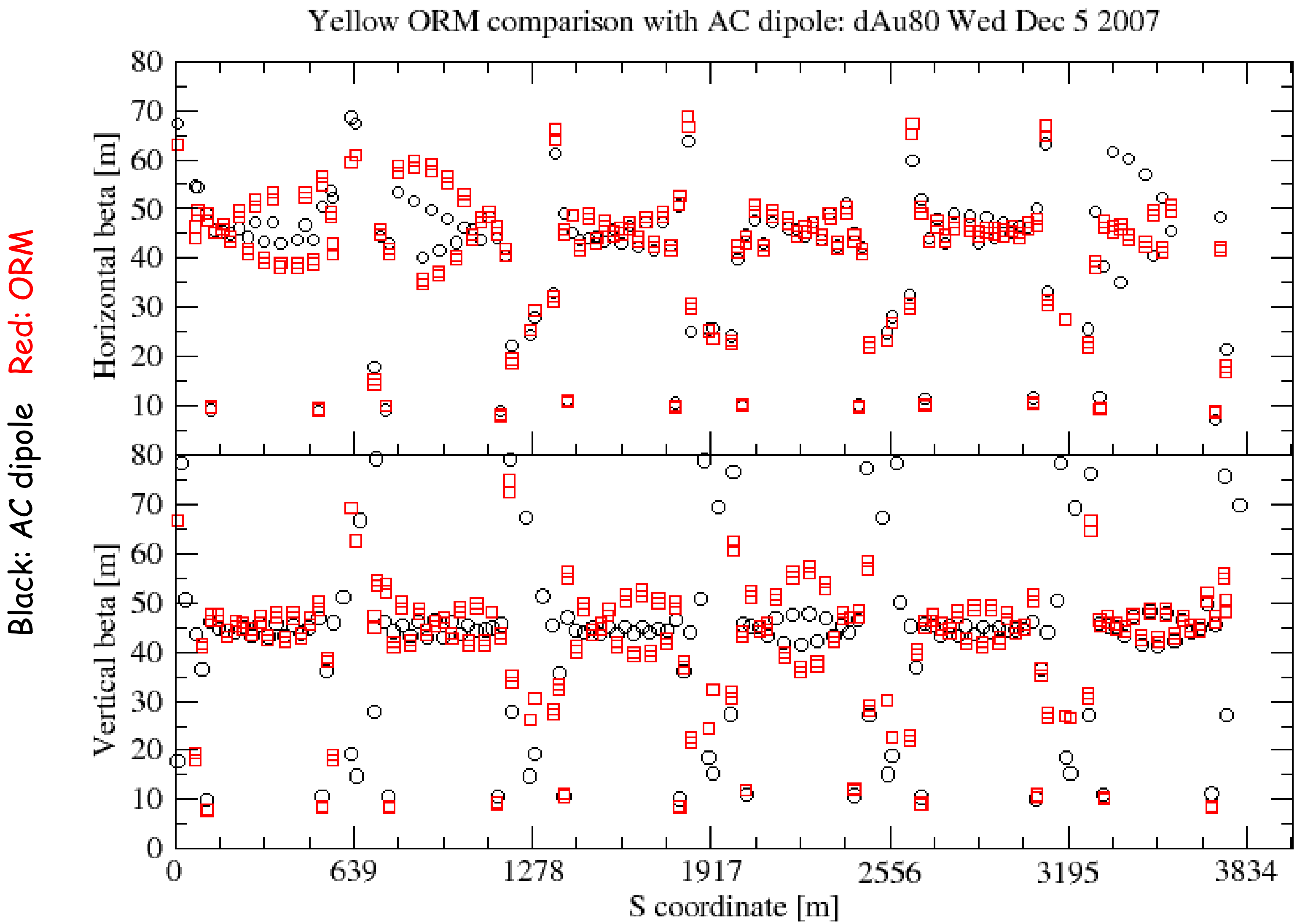
ORM Analysis I



ORM Analysis II



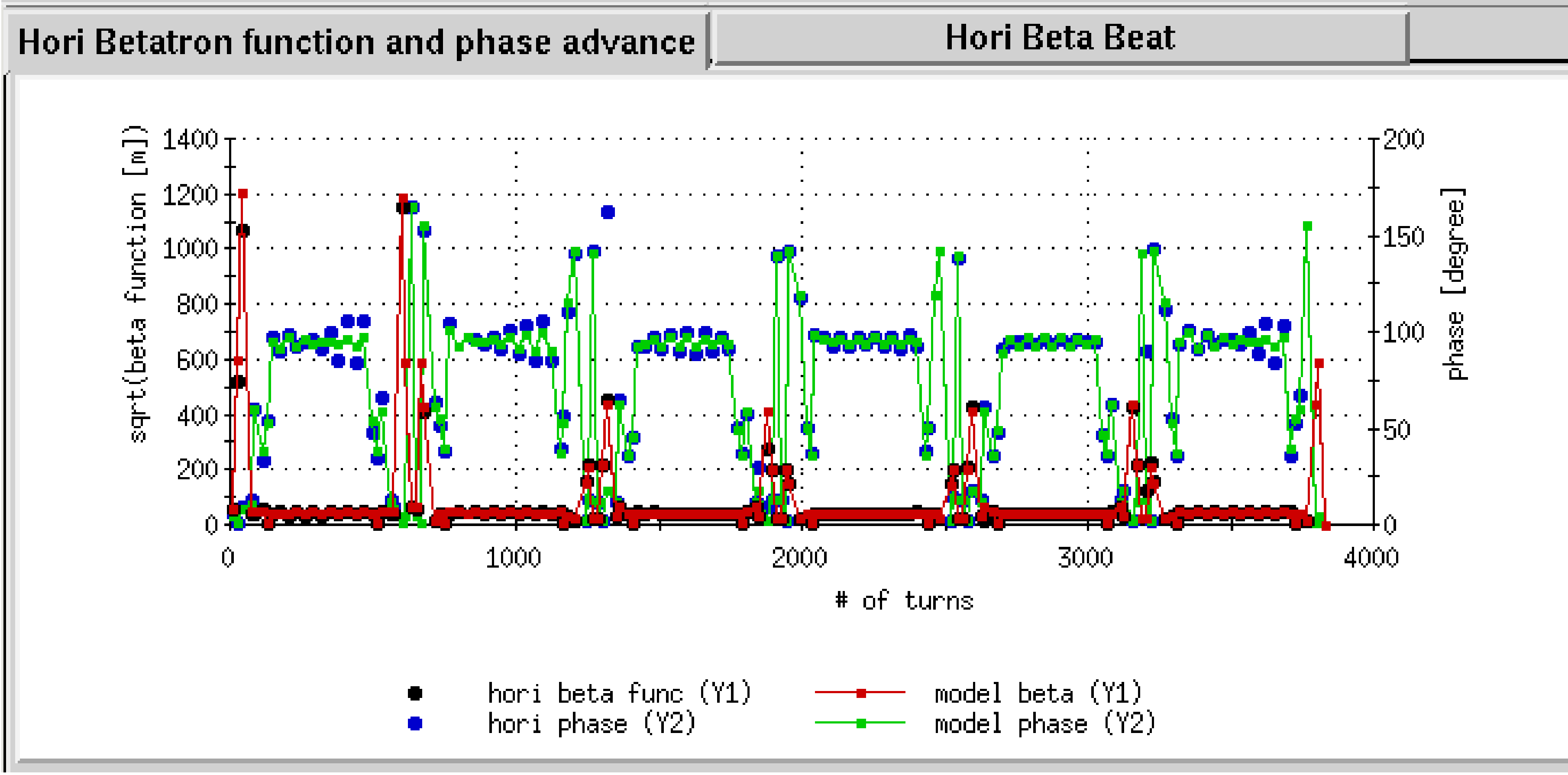
Yellow dAu80::store Beta Function Comparison



- ORM corrections applied during MD Tue Dec 11 2007
  - Applied calculated corrections only in IR6/8 low-beta triplets
  - Applied calculated tune corrections; very little beam loss
  - Average tune changes were quite small: corrections "balanced"
  - Residual beta beating in horizontal about 50% smaller
  - No apparently reduction in vertical beta beating
    - ⇨ But no degredation either

Magnet	dK [m^-2]	Length [m]	dKL [m^-1]	dKL [m^-1] (half)	dQx	dQy
yo8-qf2	0.000057	3.39	0.000193	0.000097	0.018	-0.018
yo5-qd3	0.000048	2.1	0.000101	0.000050	0.010	-0.010
yo8-qd3	0.000025	2.1	0.000053	0.000026	0.005	-0.005
yo8-qd1	0.000019	1.44	0.000027	0.000014	0.003	-0.003
yi6-qf1	-0.000011	1.44	-0.000016	-0.000008	-0.002	0.002
yi6-qd2	-0.000012	3.39	-0.000041	-0.000020	-0.004	0.004
yi6-qf3	-0.000033	2.1	-0.000069	-0.000035	-0.007	0.007
yi7-qd2	-0.000048	3.39	-0.000163	-0.000081	-0.016	0.016
				Sum of changes	0.008	-0.008

AC Dipole Data (APEX Dec 12 2007)



Continued Analysis

- Data conversion streamlined but still hand-checked
  - ~1h of work to clean up data for analysis
- Blue analysis will be started this week
  - Have been analyzing Q1-Q9, all RHIC quads: no difference!
  - Blue beta beating in dAu80 slightly better than yellow
- Discussions with Johan Bengtsson Dec 13
  - Reduce parameter space from Q1-Q9 to a few quads
  - Incrementally improve beta beat, then coupling

Minimizing χ^2

- Gradient descent: $b(n+1) = b(n) - \Delta \times \nabla \chi^2(b(n))$

- Gauss-Newton (or Taylor series):

$$b(n+1) = b(n) - H^T H \nabla \chi^2(b(n))$$

where H is the Hessian matrix of χ^2: $H_{ij} \equiv \partial^2 \chi^2 / \partial b_i \partial b_j$

- Levenberg-Marquardt combines these with a scaling parameter λ:

$$b(n+1) = b(n) - (H^T H + \lambda S^T S) \nabla \chi^2(b(n))$$

S is the singular value diagonal matrix of H.
λ=0 is Gauss-Newton; $\lambda \dashrightarrow \propto$ is Gradient descent.

Former SVD approach only minimized χ^2 as a linear function